In-Beam Gamma-Ray Spectroscopy of Target Fragmentation

E. Rodriguez-Vieitez[1,2], R.M. Clark[1], M. Cromaz[1], M.A. Deleplanque[1], M. Descovich[1], R.M. Diamond[1], P. Fallon[1], A. Görgen[1,3], G.J. Lane[1,4], I.Y. Lee[1], A.O. Macchiavelli[1], H. Mahmud[1], S.G. Prussin[2], F.S. Stephens[1], C.E. Svensson[1,5], K. Vetter[1,6], D. Ward[1]

[1] Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720
[2] Department of Nuclear Engineering, University of California, Berkeley, California 94720
[3] CEA Saclay, F-91191 Gif-sur-Yvette, France
[4] Australian National University, Canberra, Australia
[5] University of Guelph, Guelph, Ontario N1G2W1, Canada
[6] Lawrence Livermore National Laboratory, Livermore, California 94550

Fragmentation reactions, typically performed at energies ~E/A>50 MeV, produce neutron-rich nuclei but leave little angular momentum in the residues. In this work we have examined the product distribution and angular momentum input for a ^{12}C beam at 30 MeV/A on a thick (40 mg/cm^2) target of ^{51}V, testing the feasibility of in-beam gamma-ray spectroscopy of target fragmentation at this lower energy. With this technique it might be possible to study neutron-rich nuclei to moderate spins, complementing the now traditional beam fragmentation studies.

The main advantage of the target fragmentation setup is that, for lifetimes longer than the stopping time (~1 ps), gamma rays are not Doppler broadened. The experiment was performed with the Gammasphere array and the beam delivered by the 88-inch cyclotron at LBNL. The spectrum of <3 MeV gamma rays emitted within ~100 ns of the beam was analyzed using double and triple gamma-ray coincidences to identify the product nucleus from which they were emitted. The intensity of these coincidences provides the basis for determining the yields of different product nuclei.

Some 70 different isotopes from F to Fe (Z=9-26) have been identified and new excited states found. The experimental isotopic yields, such as those shown in Fig. 1, cannot be completely reproduced by LISE calculations [1] shown in Fig. 2, which are based on the abrasion-ablation model of fragmentation. The LISE code predicts a slower rate of increase of yields with increasing Z of the fragment. In addition, nuclei such as Cr, Mn and Fe (cannot be produced by fragmentation) are observed experimentally (Fig. 1).

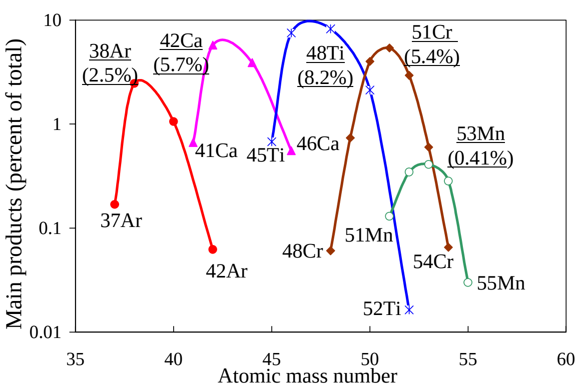

FIG. 1: Selected product yields observed in the experiment (30 MeV/A ^{12}C beam on a 40 mg/cm^2 ^{51}V target).

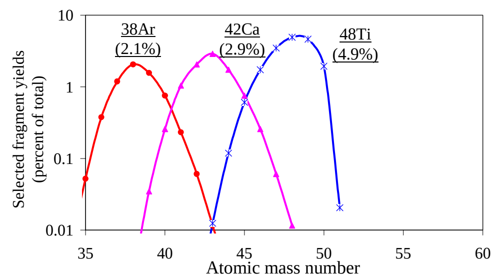

FIG. 2: Selected fragment yields predicted by LISE (30 MeV/A ^{51}V beam on a 40 mg/cm^2 ^{12}C target).

The experimental spin populations shown in Fig. 3 correspond to higher values than those predicted by a model [2] based on fragmentation. The fact that neither yields nor spin distributions can be satisfactorily modeled by pure fragmentation reflects the variety of reactions including fragmentation, transfer, deep-inelastic, incomplete fusion, etc., taking place at the relatively low beam energy of this experiment (30 MeV/A).

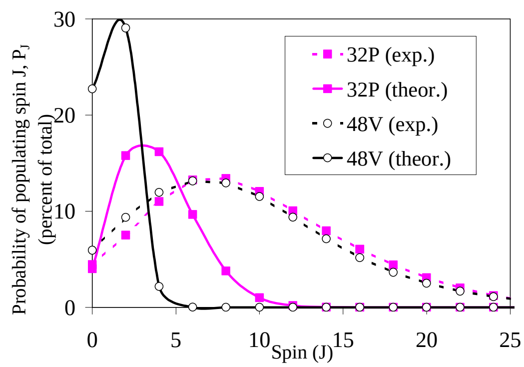

FIG. 3: Experimental and theoretical spin distributions of specific reaction products.

To conclude, this study has shown that reactions at these energies can populate higher angular momentum states and provide a new method to study exotic neutron-rich nuclei.

REFERENCES

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